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Chemical and Biochemical Characterization of Sub-Surface Water Near Distillery Industry to Evaluate Quality for End User Applications

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Abstract: Water is a universal solvent and an essential component for all living beings. Groundwater is a significant source for drinking purposes. The quality of groundwater is under threat due to anthropogenic activities. The present research is focused on the chemical. Biochemical characteristics of sub-surface water near the distillery industry and in the vicinity of the agricultural areas located in the combined East Godavari district and presents bifurcated Dr. B.R. Ambedkar Konasema district represented via groundwater sample at a distance of 0.5 km, 2kms, 4kms respectively the distillery industry as a central point. The sub surface water is characterized for chemical parameters viz… and for assessing the chemical contamination status of water sample irrigation parameters are determined to assess water sustainability for irrigation purposes.The waters are further analyzed for metal ions like… to evaluate the metal toxicity of water samples. In addition to these, the water is further analyzed for bacteria to verify bacterial contamination of water sample.The research results reveal that the sub-surface water is chemically contaminated due to the higher concentration of EC, TDS, pH, TA,Ca,Mg,Na, chloride, and metal meets water and suitable for drinking and domestic purposes. The data of metal ions indicated that the waters are contaminated exclusively with arsenic while the concatenation of other metal ions is within the permissible limits. The bacterial analysis of water indicated the presence of Enterobacteria and klebsiella.Making the waters with bacterial contamination and thereby they can cause waterborne diseases like typhoid, diarrhea, jaundice etc.Hence the waters are treated suitability with the available water-treated techniques to make the waters free from contamination before using the water for drinking purposes in order to protest the health of the public.

Keywords: *Sub surface water, irrigation, Parameter, characterization, bacteria.*

1. INTRODUCTION

Since the majority of people in rural regions still rely on groundwater for residential and drinking purposes, industrial wastewater may include dangerous levels of heavy metals such as sodium, potassium, calcium, and magnesium [Phiri et al., 2005; Chandra Ravish et al., 2017]. India's rapidly expanding a great industrial development creating strain on resource exploitation and environmental purity. Several research studies were conducted to investigate the causes and features of groundwater contamination. In the Dhampur area of the Bijnor District, Gangan, M. et al. (2016) revealed the effects of industrial effluent on the quality of sub surface water were seriously contaminated.

Industries differ greatly in the properties of their wastewater and the contaminants they contain [Kuntal et al., 2004, Chakarbarty, 1980; Lin and Tanka. 2006; Diangan et al., 2008]. When ethanol is produced, distillery industries' wastewater is drained, and this is one of the main causes of pollution in the environment. This is due to the extraordinarily high levels of inorganic solids, low pH, biological oxygen demand (BOD), and chemical oxygen demand (COD) in the effluent [Shin et al., 1992; Saha et al., 2005]. For every liter of ethanol

produced, a typical cane molasses-based distillery produces 15 liters of spent wash [Kalaiselvi and Mahimai Raja, 2009]. The high levels of nitrogen and inorganic salts in this dark brown spent wash result in high electrical conductivity (EC), which depletes oxygen and off an unpleasant odor [Chauhan, 1991; Haroon et al., 2004; Ansari et al., 2012]. Due to the improper use of distillery effluent on soil without adequate monitoring it has a negative impact on groundwater quality, altering its physicochemical characteristics, including color, pH, and electric conductivity (EC), and as a result of organic and inorganic ions leaching down [Jain et al., 2005; Priya et al., 2022]. The high salt content of spent wash can cause soil to become salty, sodic, and chemically polluted. Due to high salt concentration, spent wash has a significant effect on the characteristics of soil when it runs off onto land [Christoph et al., 2001; Ramadura and Gerard, 1994].

According to study reports, heavy metals including mercury, cadmium, and copper are present in wasted wash. These metals may accumulate up, enter the food chain, and biomagnify to dangerous levels [Kanimozhi and Vasudevan, 2010; Kathavarayan Vasanth et al., 2023]. Five distinct bacterial strains were obtained from a distillery mill site by Kaushik and Thakur (2009).Growing concern about the environmental implications of the effluents these distilleries release, particularly in relation to groundwater quality, was revealed by a study conducted in 2023 by Govind Yadav and Shafqat Alauddin understanding the effects of distillery effluents released from Saraya Distillery, Sardar Nagar on groundwater quality in the Sardar Nagar region of Gorakhpur District. show that the quality of the sub surface water has noticeably declined in the vicinity of distillery discharge locations. These contaminated water sources endanger the equilibrium of the local environment in addition to endangering the health of the residents of the area.

Keeping in view the existence of the Distillery industry and hectic agriculture activity in East Godavari district and presently bifurcated Dr. B.R. Ambedkar Konasema district of Andhra Pradesh, India the quality of drinking water must be checked at regular time intervals as there is a possibility of contamination of water sources by the released effluents so that the quality of water will be contaminated and can cause health hazards to the public who consume these water for drinking purposes.

Objectives

To characterize sub- surface water for chemical parameters to assess a chemical contamination

To determine the irrigation parameters to assess the quality of sub- surface water for utilization for irrigation purposes

To analyze metal ion concentration in sub- surface to evaluate the metal toxicity of water

To prepare correlation matrix for physico-chemical parameter to verify the correlation between the parameter

Based on the analytical data the contamination levels of the sub- surface water near distillery industry to verify its quality for use to end users like people residing in the near by habitation of the industry and farmers for utilization of the water for irrigation purposes.

To characterize sub -surface water for microbial analysis to assess the bacterial contamination

2. EXPERIMENTAL

2.1 Study Area: The proposed study area is positioned between longitude N8183’836”andN8193’72”and latitudes E1690’685”and E1693’939”. The study area map is presented in figure 1.

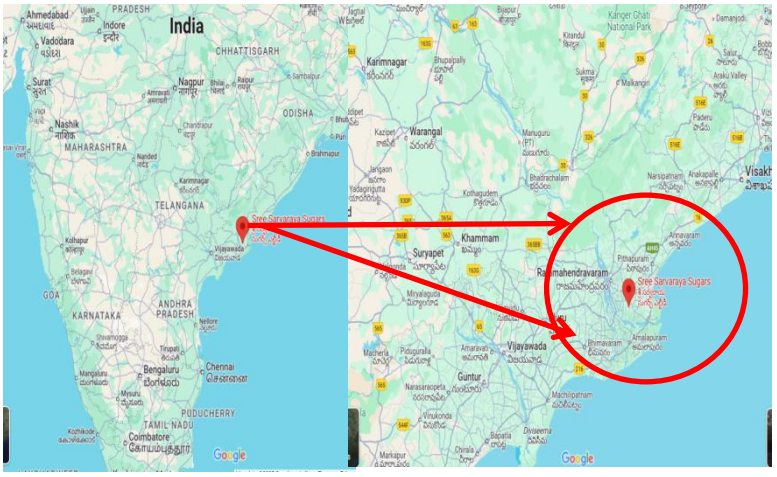


Figure 1: Locations Map of the Study Area

2.1.1 Sampling: The groundwater samples were collected using collected in Polythene containers in East, West, North and South directions around the Distillery industry by considering the industry as the nucleus at a distance of 0-0.5km,0.5-2 km and 2-4 km (Ibrahim et al., 2014) for analysis by following the standard procedures during pre and post-monsoon seasons (D.S. Ramteke, C.A. Moghe., 1988). 12 sampling areas were selected within the study area. The details of the sample code, sampling locations along with their GPS coordinates are presented in Table 1.

Table 1: Sample Code and Location

Sample Code	Sample Location	Source	Co-ordinates (GPS)		Direction& distance
			Longitude	Latitude	
D-E/1	Golla la veedhi, Ramachandrapuram	BW	E82^{0}00.982’	N16^{0}83.55’	East (0-.5km)
D-E/2	Sc colony, Pasalapudi, Road	BW	E82^{0}00.653’	N16^{0}83.795’	East(0.5-2 km)
D-E/3	Mppsschool,Palasapudi Road ,Vedurupaka	BW	E82^{0}00.685’	N16^{0}84.701’	East(2-4km)
D-W/4	MandapetaColony,Ramachandrapuram Road,	BW	E82^{0}00.927’	N16^{0}84.352’	West(0-0.5km)
D-W/5	ResidensialArea,VedurupakaRoad,Pasalapudi	BW	E82^{0}00.8941’	N16^{0}84.67’	West(0.5-2 km)
D-W/6	Swati Sri water Service,Ramachandrapuram Bypass,	BW	E82^{0}01.754’	N16^{0}84.77’	West(2-4km)
D-N/7	Anjaneyatemple, chelluru	BW	E81^{0}99.543’	N16^{0}83.015’	North(0-0.5km)
D-N/8	Machavaram Road, chelluru	BW	E81^{0}98.816’	N16^{0}83.675’	North(0.5-2 km)
D-N/9	Sai baba Temple,chelluru	BW	E81^{0}98.031’	N16^{0}84.942’	North(2-4km)
D-S/10	Residential Area,pasalapudi road,	BW	E82^{0}00.229’	N16^{0}83.446’	South(0-0.5km)
D-S/11	ResidensialArea,chelluruRoad,pasalapudi	BW	E82^{0}00.391’	N16^{0}83.799’	South(0.5-2 km)
D-S/12	Sai baba temple,AtchutapuramRoad,chelluru	BW	E81^{0}99.45’	N16^{0}82.215’	South(2-4km)

D: Distillery industry, E:East, W:West, N:North, S:South, BW:BoreWell and OW:OpenWell

2.1.2 Physicochemical Parameters

pH is measured by a portable pH Metre (Model-PCS Tester35, Eutech, UK) and Conductivity is measured by a portable EC sensor (electrode based). TDS is determined by a portable TDS sensor (electrode-based), and TH, TA and Chloride are estimated by titrimetry [Paul et al., 2017]. Total hardness was determined by EDTA titration using the Erich Arome Black-T indicator [Mohanty et al., 1997]. Total alkalinity was determined by titration with0.02NH_2SO_4 and methyl orange indicator

Chloride was determined by a titrimetric method by standard silver nitrate solution [Boehm et al., 2014]. Sulphate and phosphate by spectrophotometer (Model-106, Systronics), Sodium and potassium by a Flame photometer (Model-128, Systronics), Nitrate by using Ion selective electrode (Model-HI 3222 pH/ORP/ISE Metre, HANNA) and GPS Coordinates measured with Garmine (Germany) make-etrex30x-Model in WGS 84 decimal system are presented in Table 1 APHA (1992). A strict quality assurance and quality control programme was followed for the data quality of various parametric values.

2.1.3 Metal Ion Concentrations

The three representative samples were prepared and analyzed for metal ions viz., Cr, Mn, Fe, Co, Ni, Cu, Zn, Pb, As and Hg by Inductively Coupled Plasma Optical Emission Spectroscopy Technique (ICP-OES Model: Avio 200-Perkin Elmer optical emission spectrometer). Samples are diluted to maintain conductance less than 1000 µs/ cm and acidified with 2% and 5% HNO_3 for 100 mg/mL [Gupta et al., 1991]. Multi-element blended standard solutions are utilised for the preparation of metals working standard solution. The samples are processed as per the manual instructions of the instrument and analyzed for metals by following the standard procedures [Srivastava et al., 1998].

2.1.4 Irrigation Parameters

The irrigation parameters determined for the water include Percent Sodium (%Na), Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Kelly's Ratio (KR), Magnesium Hazard (MH) and the parameters are determined by the following relations -1,2,3&4 respectively (Kawano et al., 1992).

Percent Sodium (%Na) = $$\frac{Na^{+}X100}{Ca^{2+}+Mg^{2+}+Na^{+}+K^{+}}$$ ----- (1)

Sodium Adsorption Ratio (SAR) = $$\frac{Na^{+}}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}}$$ - ---(2)

Residual Sodium Carbonate (RSC) = (Carbonate +bicarbonate) – (Calcium+ Magnesium) (meq/l)

Kelly'sRatio(KR)= $$\frac{Na^{+}}{Ca^{2+}+Mg^{2+}}$$ ----------(3)

Magnesium Hazard (MH) = $$\frac{Mg^{2+}}{Ca^{2+}+Mg^{2+}}X100$$ - ---(4)

Microbial Analysis:

(a)Spreading:

EMB agar plates were prepared, and all the samples were spread onto a EMB agar plate under aseptic condition and incubated for 24hrs for the growth of the pathogenic bacterial colonies to isolate different bacteria

(b) Indole production test :

Bacteria which posses enzyme tryptophanase degrade ammino acid and tryptophan to indole pyruvic acid and ammonia.This test is carried out to determine the ability of microorganisams to degrade the aminoacid trytophan.The formation of indole is detected by adding kovac"s reagent. Which produce cherry red layer.

(c) Methyl -Red test :

This test is useful for determining the ability of microorganisms to oxidise glucose with the production of stabilization of high concentration of acid end products. Methyl red is the pH indicator which turns to red colour in the presence of acid .

(d) Vogesprokauer test:

This test is useful in determining the capability of some microorganisms to produce non acidic or neutral end products such as acetyl methyl carbinol from the organic acids that results from glucose metabolism. The bacterial culture when treated with Barritt's reagent gives pink colour which indicates the positiveness of the test. Barritts reagent : a mixture of alcoholic α- naphthol and KOH (40 %)

(e) Citrate utilization test

This test is significant in differing the enteric micro organisms on the basis of their ability to ferment citrate as a soul carbon source .In the absence of fermentable glucose (or) lactose some

micro organisms are capable of using citrate as a carbon source and citrase is the enzyme .which produces oxalactic acid and acetate.

2.8 Spreading

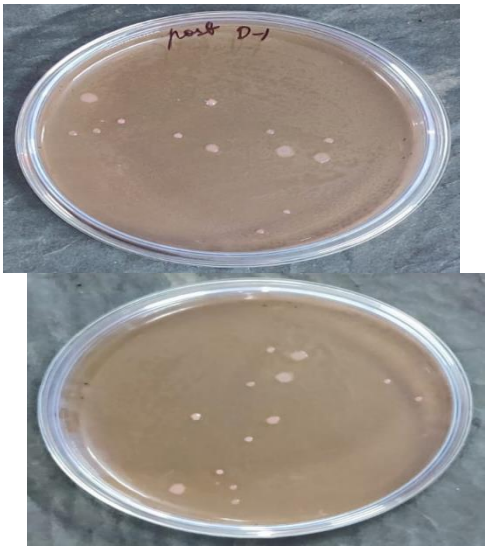


Fig2: Spreadplate of post D-1 sample

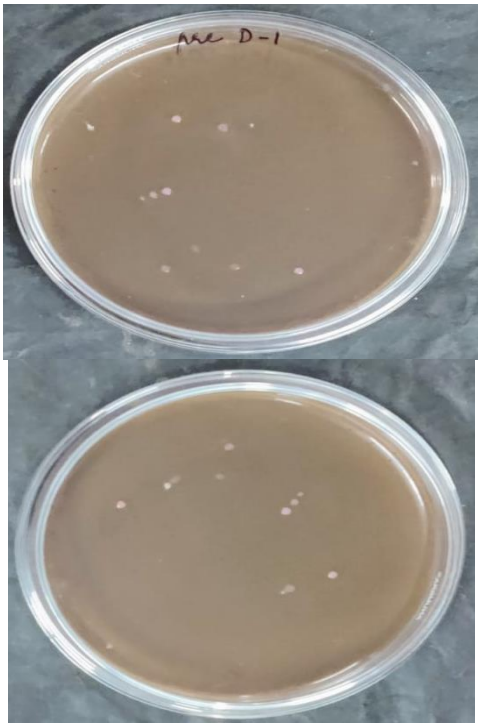


Fig3: Spreadplate of pre D-1 sample

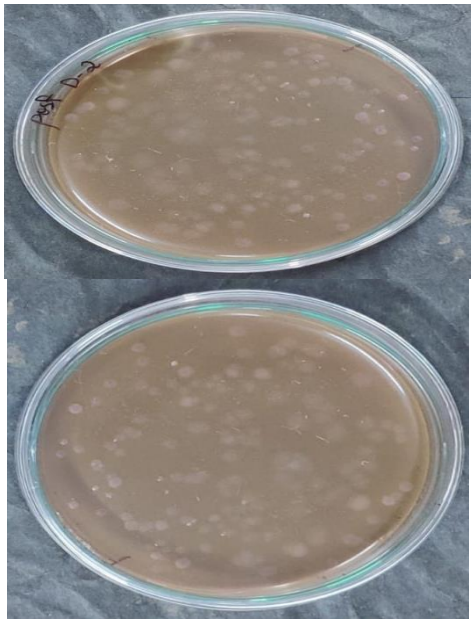


Fig4: Spreadplate of post D-2 sample

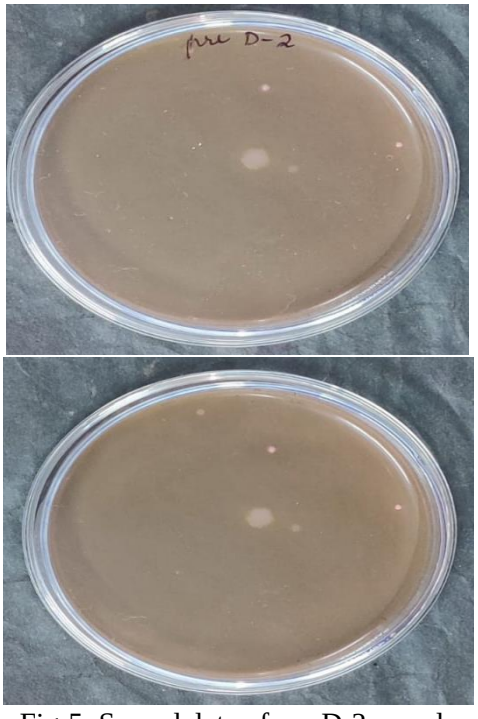
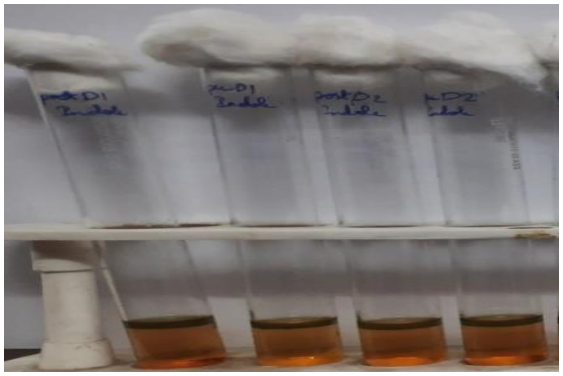
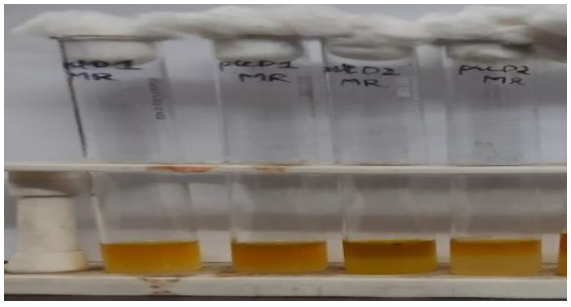
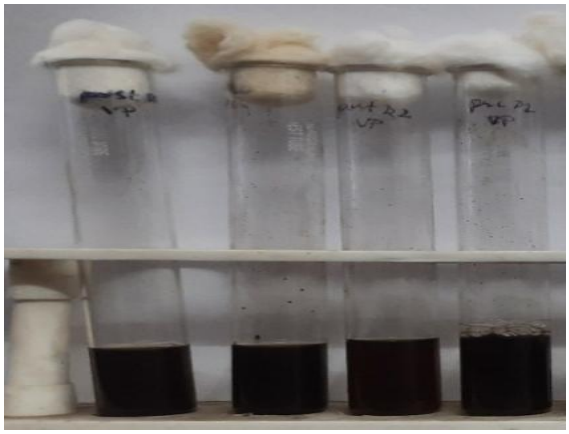
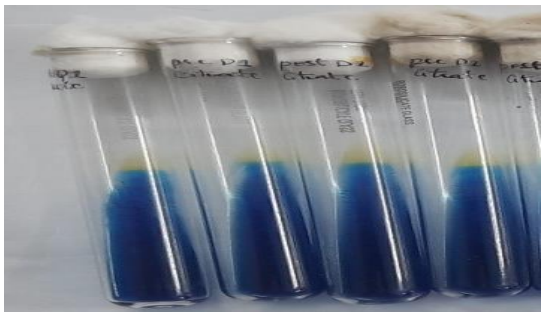


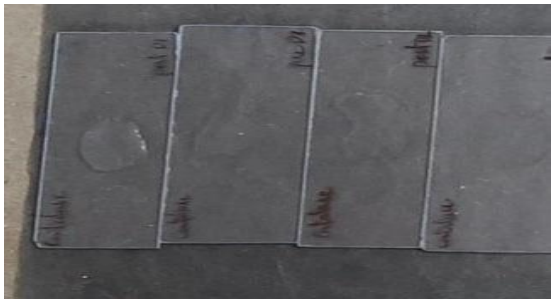
Fig-5: Spreadplate of pre D-2 sample











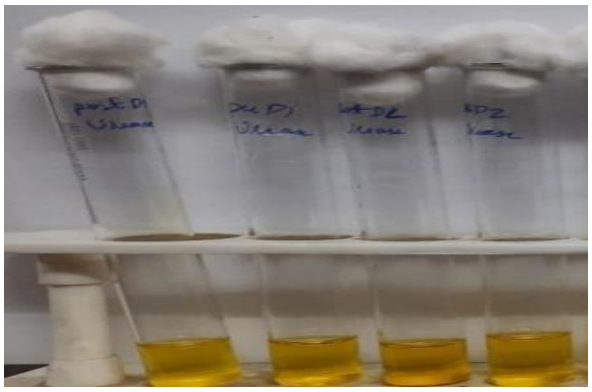


Fig-6: Indole test Fig-7: Methyl Red test

Fig-8: Voges Proskauer test

Fig-9:Citrate utilization test

Fig-10: Catalase test

Fig-11: Urease test

RESULTS AND DISCUSSION

The groundwater was characterized for physicochemical parameters and the data is presented in (Tables 2&5). Correlation matrix values are presented in (Tables 6&7) respectively. Further, the water was characterized for irrigation parameters were determined and the parametric values are presented in (Table 8).Metal ions were characterized by ICP-OES and the analytical data are presented in (Table 9) (Obiri et al., 1999a). microbial analysis are presented in (Table 9)

Table2: Physicochemical Parametric Values

Sample Code	Temp ^{0}C		pH		EC (µmhos/cm)		TDS (mg/l)		Salinity (mg/l)		TH (mg/l)		Ca H (mg/l)		Mg H (mg/l)	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
D-E/1	34.8	28.5	8.34	7.29	625	651	303	462	350	332	330	200	200	180	130	20
D-E/2	34.8	29.1	7.5	7.29	973	618	469	438	530	314	420	270	250	110	170	160
D-E/3	34.7	29.3	7.15	7.41	1150	1042	544	738	640	538	520	330	350	200	170	130
D-W/4	34.6	29.2	7.69	7.14	1690	1666	820	1180	930	876	570	450	300	180	270	270
D-W/5	34.8	29.3	8.18	7.19	1760	1882	850	1330	970	997	390	350	200	200	190	150
D-W/6	34.9	28.2	7.76	7.23	598	795	285	564	330	407	380	250	250	170	130	80
D-N/7	35	29.4	7.74	7.01	820	1610	394	1140	450	7450	350	370	200	190	150	180
D-N/8	34.5	29.1	7.66	7.34	1050	1023	505	726	580	529	340	180	300	100	40	80
D-N/9	35	29.3	7.62	7.05	2280	1139	1100	807	1250	589	640	340	300	180	340	160
D-S/10	34.9	29	7.62	7.51	517	497	247	353	290	253	360	190	200	140	160	50
D-S/11	34.8	28.1	7.77	7.71	345	326	165	232	190	166	250	170	150	140	100	30
D-S/12	35	30.3	8.11	7.46	2200	2240	1050	1590	1220	1190	250	210	150	80	100	130

Table3: Physicochemical Parametric Values

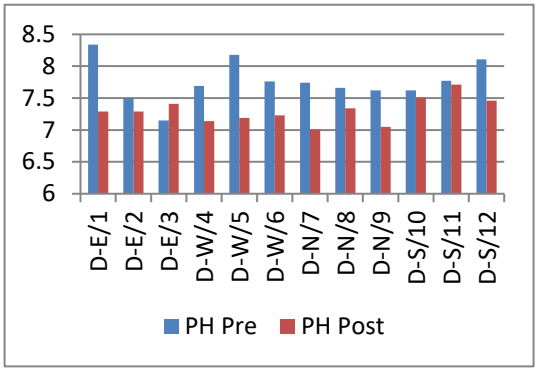
Sample Code	TA (mg/l)		HCO_3^- (mg/l)		CO_3^{2-} (mg/l)		OH^- (mg/l)	
	Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
D-E/1	160	430	2.459	7.049	0.166	0	BDL	BDL
D-E/2	200	490	2.950	6.557	0.333	1.5	BDL	BDL
D-E/3	270	700	4.426	11.475	0	0	BDL	BDL
D-W/4	300	690	4.9180	11.311	0	0	BDL	BDL
D-W/5	300	790	4.9180	11.311	0	1.666	BDL	BDL
D-W/6	200	500	3.278	8.196	0	0	BDL	BDL
D-N/7	210	860	3.442	12.459	0	1.666	BDL	BDL
D-N/8	270	650	4.426	9.508	0	1.166	BDL	BDL
D-N/9	340	630	5.573	9.180	0	1.166	BDL	BDL
D-S/10	170	420	2.786	4.426	0	2.5	BDL	BDL
D-S/11	90	260	1.475	4.262	0	0	BDL	BDL
D-S/12	330	970	5.409	14.426	0	1.5	BDL	BDL

Table4: Physicochemical Parametric Values

Sample Code	Cl- (mg/l)		SO42- (mg/l)		PO43- (mg/l)		NO3 - (mg/l)		F- (mg/l)	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
D-E/1	191.43	24.815	12.14	13.57	0.066	0.324	21.9	17.1	0.471	0.429
D-E/2	297.78	7.09	62.42	15.28	0.066	0.066	8.39	1.45	0.346	0.381
D-E/3	191.43	74.445	64.14	50.14	0.2929	0.195	6.36	3.17	0.293	0.269
D-W/4	315.51	159.53	146.85	121.14	0.105	0.23	56.9	42.7	0.201	0.194
D-W/5	315.51	127.62	95.42	108.42	3.855	2.894	108	115	0.462	0.476
D-W/6	138.26	21.27	37.28	61	0.128	0.21	3.61	3.07	0.395	0.408
D-N/7	226.88	102.81	50.71	129.42	0.101	0.089	8.9	76.2	0.380	0.339
D-N/8	244.61	49.63	41.71	51.85	0.066	0.214	6.65	4.56	0.425	0.397
D-N/9	475.03	85.08	143	53.85	0.066	0.222	104	11.7	0.385	0.156
D-S/10	244.61	3.545	9.428	10.71	0.066	0.714	6.04	1.23	0.243	0.254
D-S/11	226.88	10.635	7.7	11	0.55	0.949	3.54	1.68	0.378	0.385
D-S/12	475.03	226.88	228.28	209	0.773	0.847	14.2	8.6	0.835	0.419

Table5: Physicochemical Parametric Values

Sample Code	Calcium (mg/l)		Magnesium (mg/l))		Sodium (mg/l)		Potassium (mg/l)	
	Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
D-E/1	80	72	31.72	4.88	20.44	21.95	4.8	5.7
D-E/2	100	44	41.48	39.04	51.73	17.44	1.88	0.83
D-E/3	140	80	41.48	31.72	47.81	44.07	3.72	3.66
D-W/4	120	72	65.88	65.88	86.95	84.88	12.66	12.1
D-W/5	80	80	46.36	36.6	99.3	114	184.1	225
D-W/6	100	68	31.72	19.52	27.97	33.18	0.99	1.09
D-N/7	80	76	36.6	43.92	40.77	86.38	0.96	2.21
D-N/8	120	40	9.76	19.52	63.98	65.57	12.47	12.4
D-N/9	120	72	82.96	39.04	88.54	44.36	117.61	7.52
D-S/10	80	56	39.04	12.2	16.64	15.74	1.62	1.05
D-S/11	60	56	24.4	7.32	11.93	10.94	0.68	0.6
D-S/12	60	32	24.4	31.72	302.8	94.2	18.5	20.3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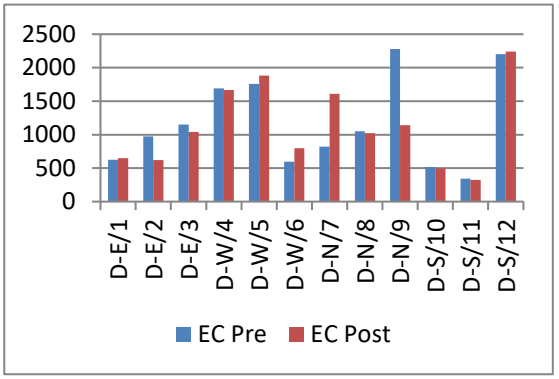
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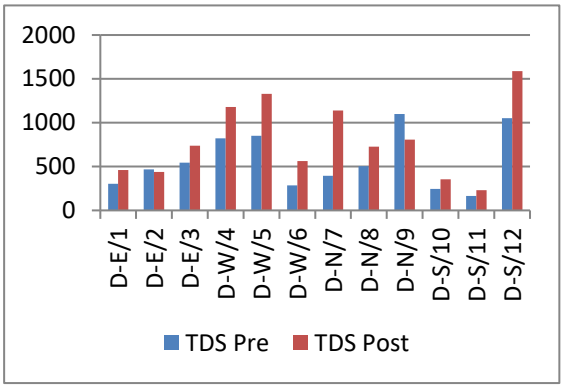
EC Pre
EC Post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D-N/8
D-N/9
D-S/10
D-S/11
D-S/12
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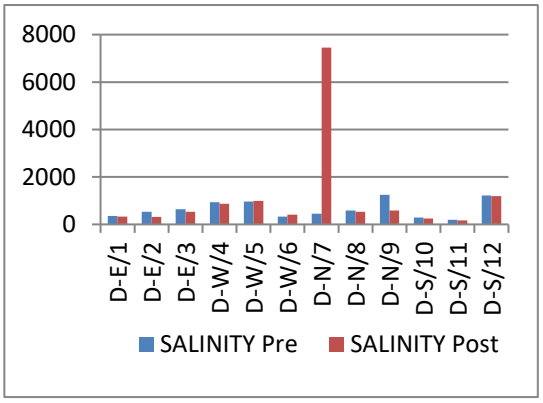
TDS Post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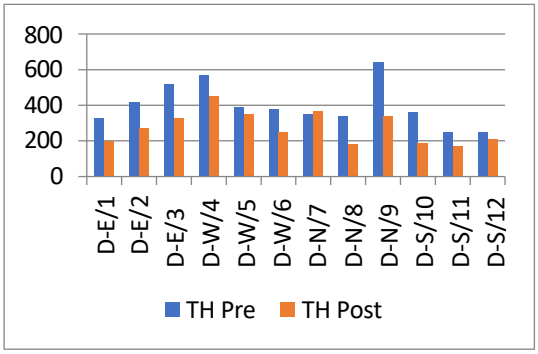
SALINITY Pre
SALINITY Post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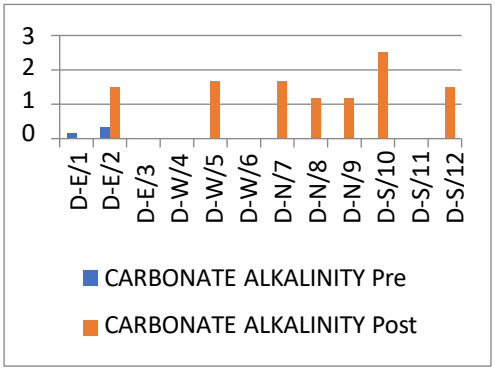
D-S/12
TH Pre
TH Post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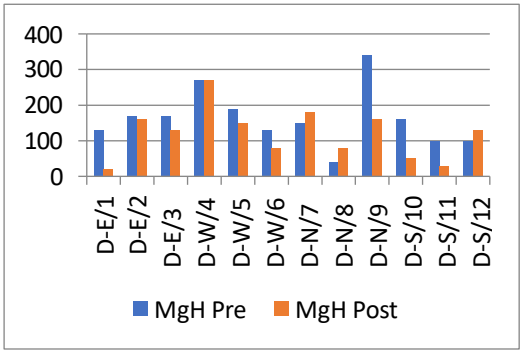
D-S/10
D-S/11
D-S/12
CARBONATE ALKALINITY Pre
CARBONATE ALKALINITY Post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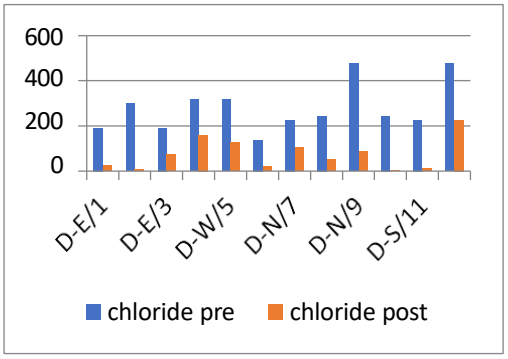
D-S/11
D-S/12
MgH Pre
MgH Post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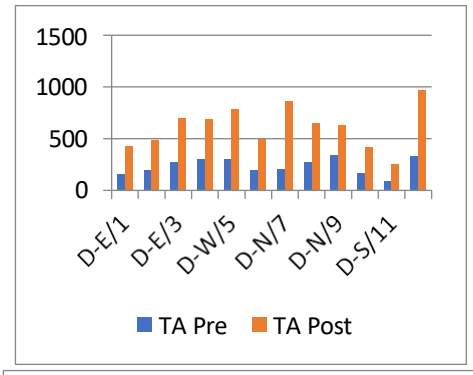
chloride post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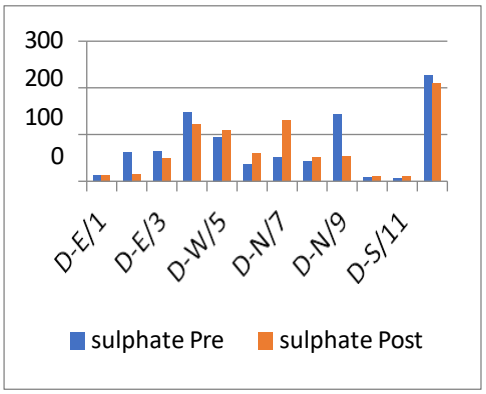
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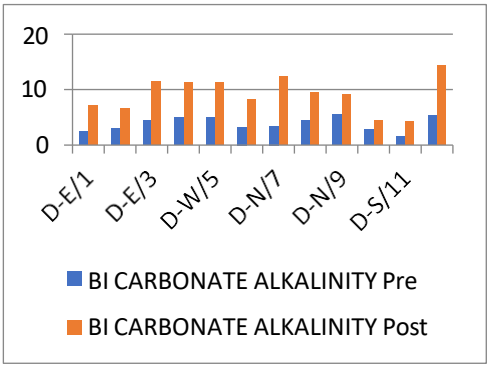
D-S/11
sulphate Pre
sulphate Post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D-S/11
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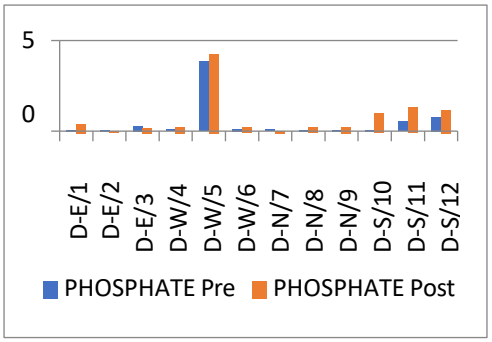
BI CARBONATE ALKALINITY Post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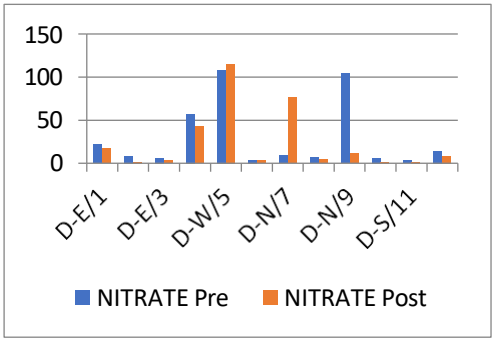
D-S/10
D-S/11
D-S/12
PHOSPHATE Pre
PHOSPHATE Post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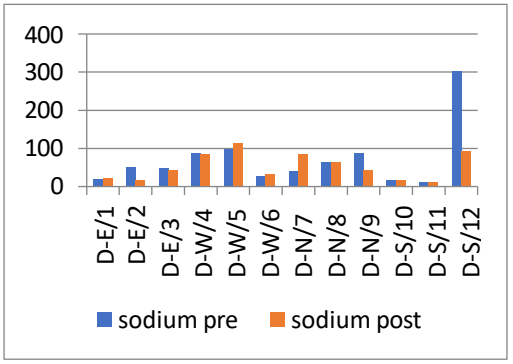
NITRATE Post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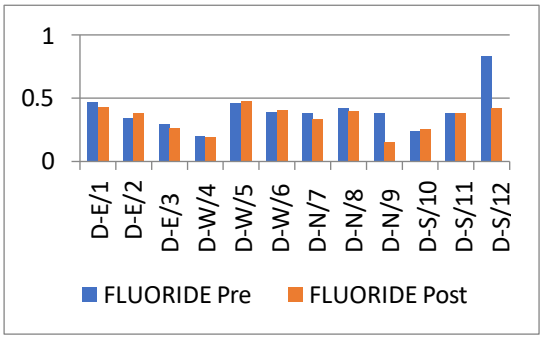
D-S/10
D-S/11
D-S/12
sodium pre
sodium post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0.5
0
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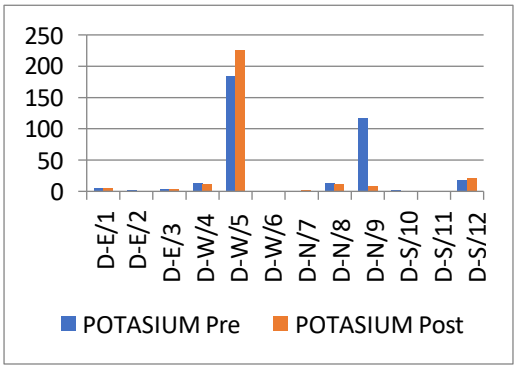
D-S/10
D-S/11
D-S/12
FLUORIDE Pre
FLUORIDE Post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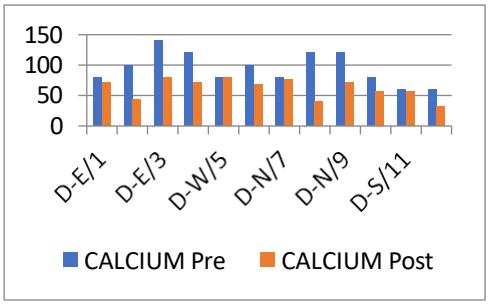
D-N/9
D-S/10
D-S/11
D-S/12
POTASIUM Pre
POTASIUM Post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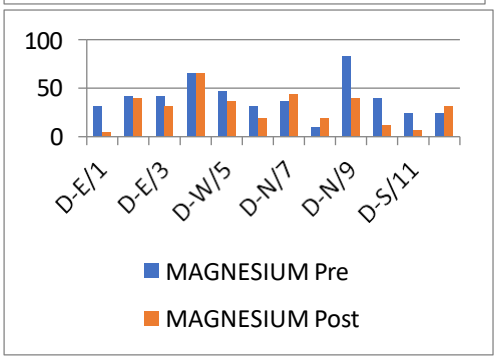
D-N/7
D-N/9
D-S/11
CALCIUM Pre
CALCIUM Post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50
0
D-E/1
D-E/3
D-W/5
D-N/7
D-N/9
D-S/11
MAGNESIUM Pre
MAGNESIUM Post

Table-6: Correlation Matrix of Physicochemical parametric data

Pre Monsoon															
	pH	*EC*	*TDS*	*TH*	*TA*	*D.O*	HCO_3^-	Cl^-	SO_4^{2-}	PO_4^{3-}	NO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
pH	1														
EC	0.114	1													
TDS	0.117	0.999	1												
TH	-0.495	0.470	0.475	1											
TA	-0.036	0.930	0.929	0.534	1										
D.O	0.642	0.04	0.053	-0.29	-0.01	1									
HCO3-	-0.037	0.923	0.922	0.52	0.99	-0.02	1								
Cl-	0.162	0.876	0.876	0.25	0.69	0.21	0.678	1							
SO42-	0.140	0.922	0.919	0.27	0.83	0.07	0.825	0.849	1						
PO43-	0.445	0.324	0.326	-0.13	0.26	0.06	0.273	0.179	0.18	1					
NO3-	0.264	0.699	0.707	0.566	0.59	0.16	0.599	0.563	0.44	0.586	1				
Ca2+	-0.679	0.214	0.215	0.797	0.44	-0.45	0.432	-0.08	0.04	-0.28	0.16	1			
Mg2+	-0.2	0.540	0.546	0.871	0.45	-0.07	0.444	0.462	0.38	0.03	0.73	0.39	1		
Na+	0.316	0.761	0.755	-0.134	0.67	0.14	0.667	0.760	0.89	0.248	0.19	-0.23	-0.016	1	
K+	0.3123	0.607	0.612	0.321	0.52	0.12	0.532	0.479	0.33	0.79	0.92	0.01	0.479	0.216	1

Table-7: Correlation Matrix Physicochemical parametric data

Post Monsoon															
	pH	*EC*	*TDS*	*TH*	*TA*	*D.O*	HCO_3^-	Cl^-	SO_4^{2-}	PO_4^{3-}	NO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
pH	1														
EC	-0.43	1													
TDS	-0.43	1	1												
TH	-0.73	0.52	0.523	1											
TA	-0.47	0.94	0.942	0.492	1										
D.O	0.35	-0.17	-0.17	-0.58	-0.06	1									
HCO_3^-	-0.47	0.92	0.926	0.54	0.96	-0.17	1								
Cl^-	-0.28	0.95	0.959	0.471	0.86	-0.28	0.88	1							
SO_4^{2-}	-0.30	0.95	0.953	0.393	0.89	-0.18	0.88	0.945	1						
PO_4^{3-}	0.13	0.34	0.346	0.025	0.16	0.38	0.10	0.263	0.217	1					
NO_3^-	-0.53	0.59	0.597	0.59	0.5	0.05	0.45	0.426	0.443	0.646	1				
Ca^{2+}	-0.49	0.03	0.036	0.639	0.01	-0.17	0.10	-0.04	-0.10	0.157	0.52	1			
Mg^{2+}	-0.64	0.64	0.639	0.898	0.61	-0.63	0.62	0.618	0.558	-0.06	0.446	0.23	1		
Na^+	-0.46	0.94	0.948	0.541	0.88	-0.15	0.86	0.853	0.858	0.458	0.746	0.12	0.61	1	
K^+	-0.18	0.46	0.461	0.261	0.32	0.285	0.27	0.316	0.268	0.928	0.787	0.29	0.16	0.60	1

Table-8: **Irrigation parametric values of ground waters**

Sample Code	% Na (me/l)		SAR (me/l)		RSC (me/l)		Kelly's Ratio		MH	
	Monsoon		Monsoon		Monsoon		Monsoon		Monsoon	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
D-E/1	11.766	18.746	0.694	0.955	BDL	3.059	0.315	0.239	38.8	9.774
D-E/2	21.186	12.422	1.55	0.657	BDL	2.734	0.27	0.412	39.88	58.66
D-E/3	16.635	22.41	1.293	1.499	BDL	4.933	0.201	0.293	32.15	38.8
D-W/4	24.58	28.67	2.25	2.478	BDL	2.44	0.335	0.416	46.76	59.41
D-W/5	25.799	28.16	3.112	3.765	BDL	6.048	0.56	0.715	48.153	42.26
D-W/6	13.852	22.42	0.886	1.295	BDL	3.235	0.161	0.29	33.66	31.46
D-N/7	20.311	33.75	1.347	2.77	BDL	6.803	0.255	0.513	42.27	43.11
D-N/8	28.15	42.37	2.137	3.022	BDL	7.613	0.41	0.8	11.5	43.83
D-N/9	19.746	21.8	2.166	1.487	BDL	4.123	0.304	0.286	52.51	46.45
D-S/10	9.166	15.247	0.541	0.7	BDL	3.15	0.101	0.181	43.84	25.84
D-S/11	9.44	12.258	0.465	0.516	BDL	0.875	0.104	0.14	39.41	17.28
D-S/12	73.23	46.79	11.83	4.03	0.457	11.783	2.658	0.989	39.41	61.32

Table-9: Details of Metal ion Concentrations

SAMPLE CODE	Cr (µg/L)	Mn (µg/L)	Fe (µg/L)	Co (µg/L)	Ni (µg/L)	Cu (µg/L)	Zn (µg/L)	Pb (µg/L)	As (µg/L)	Hg (µg/L)
Pre monsoon season										
D-E/1	ND	ND	ND	ND	ND	ND	ND	ND	12.88	ND
D-W/1	ND	ND	ND	ND	ND	ND	ND	ND	11.72	ND
D-N/1	ND	ND	ND	ND	ND	ND	ND	ND	10.14	ND
D-S/1	ND	ND	ND	ND	ND	ND	ND	ND	14.04	ND
Post monsoon										
D-E/1	ND	ND	ND	ND	ND	ND	ND	ND	19.06	ND
D-W/1	ND	ND	ND	ND	ND	ND	ND	ND	10.27	ND
D-N/1	ND	ND	ND	ND	ND	ND	ND	ND	7.938	ND
D-S/1	ND	ND	ND	ND	ND	ND	ND	ND	14.60	ND

Table-10: Details of Microbial Analysis

Sample Code	PRE D1	POST D1	PRE D2	POST D2
Morphology	Pink	Pink	Pink	Light purple centred
No. Of colonies	4	6	2	112
Gram staining	-ve	-ve	-ve	-ve
Motility	motile	motile	Motile	motile
Indole	-ve	-ve	-ve	-ve
MR	-ve	+ve	-ve	-ve
VP	+ve	-ve	-ve	+ve
Citrate	+ve	+ve	+ve	+ve
Catalase	-ve	+ve	-ve	-ve
Urease	-ve	-ve	-ve	-ve
Bacteria identified	*Enterobacter*	*Enterobacter*	*Klebsiella*	*Enterobacter*

2.2 Physicochemical Parameters

pH: pH levels during pre monsoon and post monsoon seasons range from 7.15 – 8.34 and 7.01-7.71 respectively near study area . pH values of ground waters near Agricultural activity areas are within the permissible limits of drinking water standards 6.5 – 8.5.

EC: EC levels range from 345-2280 µmhos/cm and 326-2240 µmhos/cm in ground waters in thestudy areas during pre and post monsoon seasons.

TDS: TDS of ground waters in the study area range from 165-1100 mg/l during pre monsoon season while TDS ranges from 232-1590 mg/l during post monsoon season

Salinity: Salinity of ground waters in the study area range from 190-1250 mg/l during pre monsoon season while it ranges from 166-7450 mg/l during post monsoon season.

TH: TH values of ground waters in the study area range from 250-640 mg/l during pre monsoon season while it ranges from 170-450 mg/l during post monsoon season.

CaH: CaH values of ground waters in the study area range from 150-350 mg/l during pre monsoon season while it ranges from 80-200 mg/l during post monsoon season.

MgH: MgH values of ground waters in the study area range from 40-340 mg/l during pre monsoon season while it ranges from 20-270 mg/l during post monsoon season.

TA: TA values of ground waters in the study area range from 90-340 mg/l during pre monsoon

season while it ranges from 260-970 mg/l during post monsoon season.

CO_3^{2-}: Carbonate levels of waters in the study area during pre monsoon seasons were observed at BDL where during post monsoon except P-N/8 and P-S/12 remaining samples observed at BDL.

HCO_3^-: Bicarbonate values of waters in the study area range from 1.475-5.573 mg/l during pre monsoon season and it ranges from 4.262-14.426 mg/l during post monsoon season

Chloride: Chloride ion concentration in waters in the study area during pre monsoon season varies from 138.26-475.03 mg/l and it ranges from 3.545-226.88 mg/l during post monsoon period. All these values are within the permissible limits of drinking water standards.

Sulphate: Sulphate ion concentration in waters in the study area during pre monsoon season varies from 7.7-228.8mg/l and it ranges from 10.71-209 mg/l during post monsoon period. All these values are within the permissible limits of drinking water standards.

Phosphate: Posphate ion concentration in waters in the study area during pre monsoon season varies from 0.066-3.855 mg/l and it ranges from 0.066-3.855 mg/l during post monsoon period. Highervalues are above the permissible limit(5 mg/l).Higher Phosphate levels indicating the discharge of Agricultural run off into the water sources.

Nitrate: Nitrate ion concentration in waters in the study area during pre monsoon season varies from 3.54-108 mg/l and it ranges from 1.23-115 mg/l during post monsoon period.

Ca^{2+}: Calcium ion concentration in waters in the study area during pre monsoon season varies from 60-140mg/l and it ranges from 32-80 mg/l during post monsoon period

Mg^{2+}: Magnesium ion concentration in waters in the study area during pre monsoon season varies from 9.76-82.96 mg/l and it ranges from 4.88-65.88 mg/l during post monsoon period

Na^+: Sodium ion concentration in waters in the study area during pre monsoon season varies from 11.93-302.8 mg/l and it ranges from 10.94-114 mg/l during post monsoon period**.**

K^+: Potassium ion concentration in waters in the study area during pre monsoon season varies from 0.68-184.1mg/l and it ranges from 0.60-225 mg/l during post monsoon period**.**

2.3 Correlation

Pre-monsoon: EC is strongly correlated with TDS, TA, HCO_3^-, Cl^-, SO_4^{2-}. TDS is strongly correlated with TA, HCO_3^-, Cl^-, SO_4^{2-}. TH is strongly correlated with Mg^{2+}. TA is strongly correlated with HCO_3^-, SO_4^{2-}. HCO_3^- is strongly correlated with SO_4^{2-}. Cl^- is strongly correlated with SO_4^{2-}. SO_4^{2-} is strongly correlated with Na^+. NO_3^- is strongly correlated with NO_3^-

Post-monsoon: EC is strongly correlated with TA, HCO_3^-, Cl^-, SO_4^{2-}, Na^+. TDS is strongly correlated with TA, HCO_3^-, Cl^-, SO_4^{2-}, Na^+. TH is strongly correlated with Mg^{2+}. TA is strongly correlated with HCO_3^-, Cl^-, SO_4^{2-}, Na^+. HCO_3^- is strongly correlated with Cl^-, SO_4^{2-}, Na^+. Cl^- is strongly correlated with SO_4^{2-}, Na^+. SO_4^{2-} is strongly correlated with Na^+. PO_4^{3-} is strongly correlated with K^+

Metal Ions

Concentrations of Fe, Co, Ni, Cu, Zn, Pb, Hg, Cr and Mnin these water are observed <5.0 µ g/l in both pre and post-monsoon. Arsenic concentrations are observed with 10.14 – 14.04 µg/L in pre-monsoon and 7.94-19.06 µg/L in post-monsoon.

2.4 Irrigation Parameters

Percent Sodium in waters during pre-monsoon season ranges from 9.166-73.230 me/l is indicate all the samples are within the permissible limit (60 me/l) except D-S/12. During post-monsoon season % Na level ranges from 12.258-46.790 me/l which are within the permissible limit. SAR in water samples during pre and post-monsoon seasons range from 0.465-11.830 and 0.516-4.030 me/l respectively and the values are within the permissible limits of irrigation standards (26 me/l). RSC values in water samples during pre-monsoon were found at BDL except sample D-S/12 having value 0.457 me/l while during the post-monsoon season in samples it ranges from and 0.875-11.783

me/l. Kelly's Ratio in water samples during pre-monsoon season ranges from 0.101-2.658 me/l and during the post-monsoon season it ranges from 0.140-0.989 me/l. All the values are within the permissible limit(1) except in the sample D-S/12 during pre monsoon with the value 2.658 me/l. Magnesium Hazard values in water during pre-monsoon season ranges from 11.500 – 52.510 while during post-monsoon season MH ranges from 9.774-61.320.

The results show that all three water samples were contaminated with Enterobacteria and Klebsiella, with concentrations ranging from 180 to 300 CFU/mL and 120 to 200 CFU/mL, respectively.The presence of *Enterobacteria and Klebsiella* in the water samples is a concern for public health, as these bacteria can cause a range of illnesses, including urinary tract infections, pneumonia, and sepsis.The concentrations of *Enterobacteria and Klebsiella* detected in this study are higher than the recommended limits set by the World Health Organization (WHO) and the Environmental Protection Agency (EPA). The contamination of water with *Enterobacteria and Klebsiella* may be attributed to several factors, including inadequate wastewater treatment, agricultural runoff, and poor sanitation practices.

3. CONCLUSIONS

The higher parametric values of Electrical Conductivity, Nitrate, Phosphate Calcium, Magnesium, Sodium and Potassium in the majority of water samples indicated chemical contamination of water in the study area indicating the unsuitability of water for drinking and domestic purpose of Fe, Co, Ni, Cu, Zn, Pb, Hg, Cr and Mn The concentration of metal ions viz are below detective limits in the both the seasons of of pre- and post-monsoon. But these water samples were observed with Arsenic concentrations in the range of 10.14 – 14.04 µg/L in pre-monsoon and 7.94-19.06 µg/L in post-monsoon, indicating the arsenic contamination of these water. The irrigation parametric values %Na, SAR, RSC, Kelly's Ratio and Magnesium Hazard except RSC indicated the suitability of majority of the waters for irrigation purposes. Correlation Matrix of revealed a strong correlation between the parametric values of EC, TH and ionic concentrations like Nitrate, Phosphate, Calcium, Magnesium, Sodium and Potassium. The research results revealed that these waters were to be treated properly by suitable treatment techniques available to protect the health of the people who consume this water for drinking and domestic purposes. This study highlights the need for regular monitoring of water quality and the implementation of effective measures to prevent the contamination of water with pathogenic bacteria.

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Conflict of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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